Fluid Phase Equilibria 427 (2016) 429–437

Contents lists available at ScienceDirect

Fluid Phase Equilibria

journal homepage: www.elsevier.com/locate/fluid

Measurements for isobaric specific heat capacity of ethyl fluoride (HFC-161) in liquid and vapor phase

Shaohua Lv, Xiaoming Zhao*, Yu Liu

MOE Key Laboratory of Thermo-Fluid Science and Engineering, Xi'an Jiaotong, University, Xi'an, Shaanxi 710049, China

ARTICLE INFO

Article history:
Received 10 May 2016
Received in revised form
29 July 2016
Accepted 29 July 2016
Available online 30 July 2016

Keywords:
Isobaric specific heat capacity
HFC-161
Liquid and vapor phase
Flow calorimeter

ABSTRACT

In this paper, a flow calorimeter was developed to measure the isobaric specific heat capacity of ethyl fluoride (HFC-161) in both liquid and vapor phase. 161 data of isobaric heat capacity of HFC-161 were obtained in liquid phase at temperatures from 303.51 K to 383.71 K and pressures up to 12.0 MPa 38 data were acquired in vapor state in the temperature range of 315.43 K–365.40 K and pressures from 1.0 MPa to 3.0 MPa. The uncertainties of the heat capacity for HFC-161 were estimated to be less than 1.0% in liquid phase and 1.5% in vapor phase, respectively. The equations of state based on specifying the Helmholtz free energy were employed to calculate the isobaric heat capacity for HFC-161. In addition, the experimental values of heat capacity in liquid phase were also compared with the literature data.

© 2016 Elsevier B.V. All rights reserved.

1. Introduction

Ethyl fluoride (HFC-161) is recently considered a promising refrigerant due to its excellent cycle performance. In addition, it has zero ozone-depletion potential (ODP) and a very low global warming potential (GWP) of 12. It has not been widely used in engineering applications for its flammability, but the rosy prospect makes it a very valuable alternative. The thermophysical properties of HFC-161 are necessary for the scientific research and engineering applications. Some thermophysical properties of HFC-161 have been published in recent years, such as the gaseous PVT properties [1], surface tension [2], viscosity [3,4] in liquid and vapor phase, and the thermal conductivity [5]. Its heat capacity in liquid phase was measured with a C80 by He [6] in 2015.

In this work, the isobaric heat capacity of HFC-161 was investigated by means of a flow calorimeter. 161 data of heat capacity for HFC-161 were acquired at temperatures from 303.51 K to 383.71 K and pressures up to 12.0 MPa 38 data were obtained in vapor phase in the temperature range from 315.43 K to 365.40 K. Those data are very useful for research and applications of HFC-161.

2. Experiment

2.1. Material

The sample of HFC-161 was supplied by Zhejiang Lantian Environmental Protection Hi-tech Co.Ltd. The mass fraction purity was greater than 99.95%. No further purification was done before use. The detailed information of the sample used in this study was summarized in Table 1.

2.2. Apparatus

The schematic of the experiment system is shown in Fig. 1. The apparatus fundamentally includes several parts: an air thermostatic bath without a cooling system, flow calorimeter, a mass flowmeter, temperature and pressure measuring systems, vacuum system. Among them, the calorimeter consists of a heater, two thermometers and a vacuum cylinder.

Fig. 2 shows the structure of the calorimeter. Two platinum resistance thermometers were embedded into the stainless steel annular tube to take temperatures at the inlet and outlet. An electrical heating rod was put into the middle annular tube. The thermometers and heater were powered by high-resolution DC power supply (Keithley 2400 SourceMeter). A constant-flux pump (2PB3020, SZWEICO) delivers the sample through the system at a set constant flow which was measured by a high-precision mass flow meter (SIEMENS MASS2100 DI1.5). The stable pressures

---

* Corresponding author.
E-mail address: xmzhao@mail.xjtu.edu.cn (X. Zhao).

http://dx.doi.org/10.1016/j.fluid.2016.07.034
0378-3812/© 2016 Elsevier B.V. All rights reserved.

Table 1
Samples used in this paper.

Chemical name	Source	Initial mass fraction purity	Purification method
HFC-161 (ethyl fluoride)	Zhejiang Lantian Environment Protection Hi-Tech Co.Ltd	0.9995	none
Water	Deionized water	0.9999	none

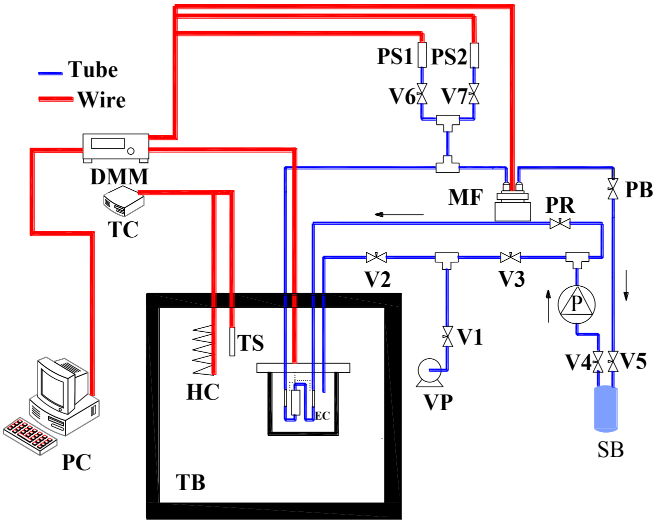

Fig. 1. Schematic diagram of the experiment system. TB, air thermostatic bath; EC, Experimental cell; TS, Thermometer; HC, Heater; TC, High accuracy temperature controller; DMM, Keithley 2700 data acquisition system; PC, Computer; PS1, PS2, Pressure sensor; MF, Siemens mass flowmeter; VP, Vacuum pump; SB, Sample bottle; V1–V7, Needle valve; PR, Pressure reducing valve; PB, Back pressure valve; P, Constant-flux pump.

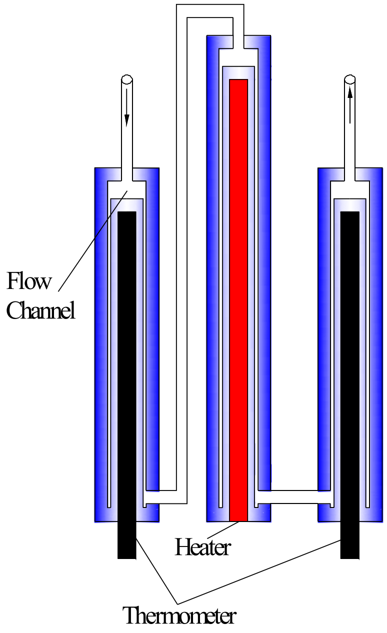

Fig. 2. Sketch of the calorimeter.

measured by a electronic pressure transmitter (supplied by Micro Sensor Co., Ltd) were maintained by adjusting a pressure reducing valve and back pressure valve. The electrical signals generated by the experimental system were acquired by a multimeter (Keithley 2700) connected to a computer and converted into temperatures, pressures, mass flow rate, and electric power with a LabView program.

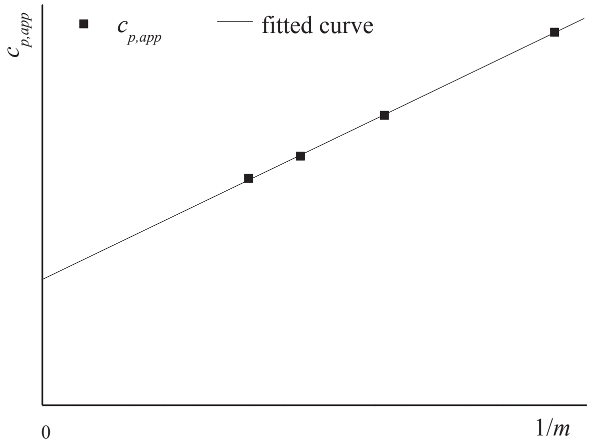

Fig. 3. The relation between $c_{p,app}$, c_p and $1/m$.

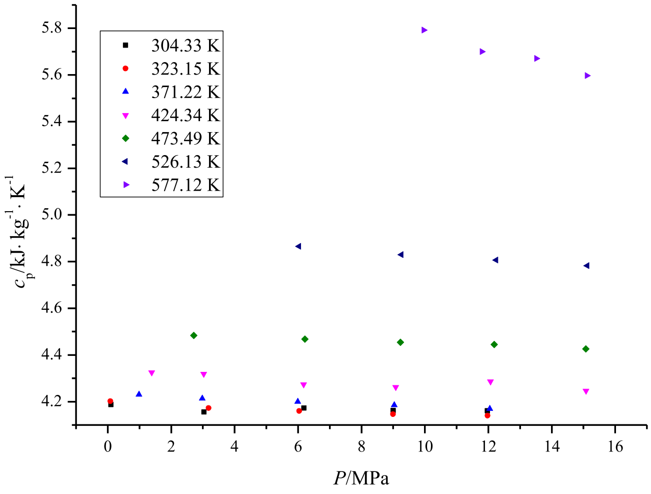

Fig. 4. Measured isobaric heat capacity of water.

2.3. Experiment procedure

When the air bath is at a constant temperature, before the sample flow there is a small temperature difference $\varDelta T_1$ between the thermometers used in the calorimeter; besides, there would be another temperature difference $\varDelta T_2$ caused by Joule-Thomson effect after the sample flows. During the experiment, the sample flow will receive a heat flux generated by the heater. At the constant pressure, by measuring the sample flow's inlet and outlet temperatures (T_1 andT_2), power of the heater (Q) and the mass flow rate (m) in the calorimeter, the heat capacity can be calculated by equation (1).

$$c_{p,app} = \frac{Q}{m \cdot \Delta T} \tag{1}$$

Download English Version:

https://daneshyari.com/en/article/6619448

Download Persian Version:

https://daneshyari.com/article/6619448

Daneshyari.com